



**S. Holland**

**LBNL**

**January 26<sup>th</sup>, 2001**

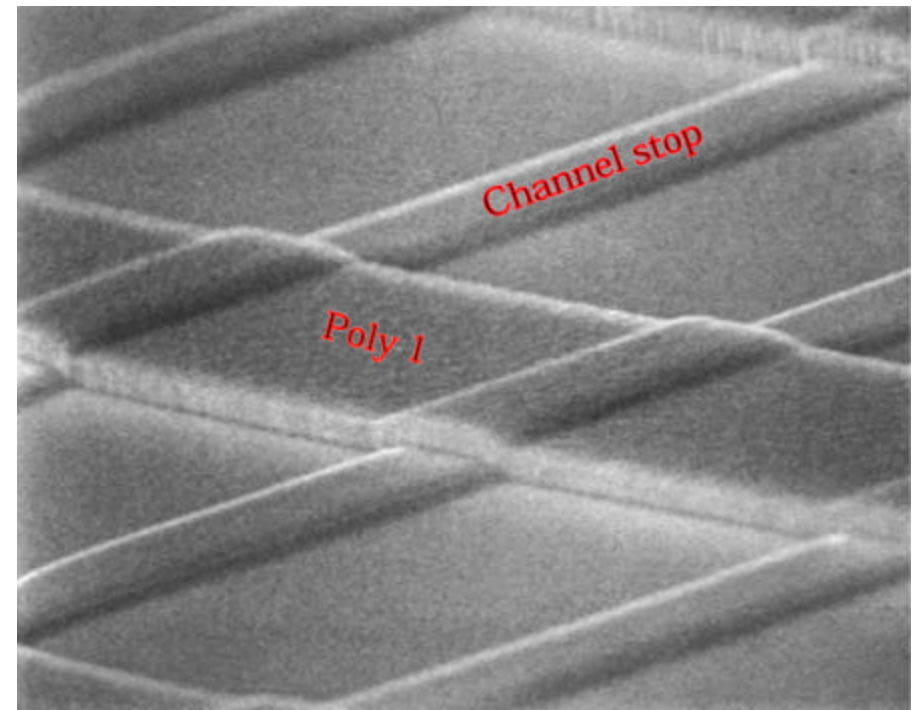
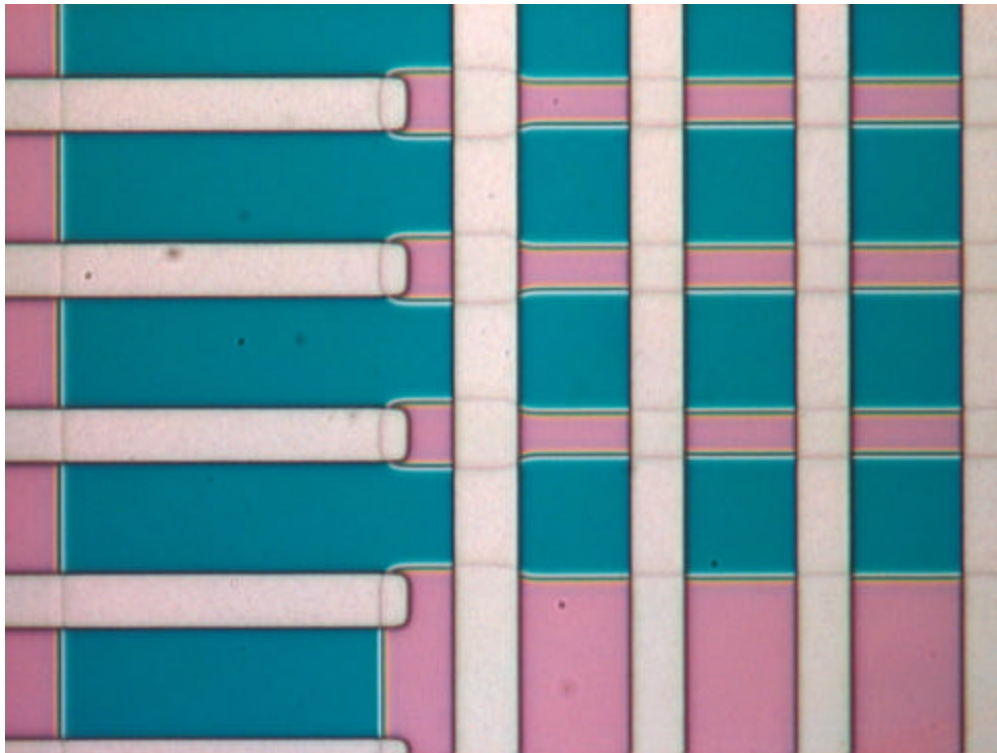
## **Outline**

- **MicroSystems Laboratory**
- **CCD Technology**
- **Point Spread Function**
- **Background radiation issues**



- | The MicroSystems Lab was conceived by the LBNL Physics Division to support the detector R&D effort for the Superconducting SuperCollider
- | The MSL is a Class 10 clean room dedicated to high-purity silicon fabrication
- | Includes full CCD fabrication capability except ion implantation (3 commercial vendors in the Bay Area)
- | Equipment includes:
  - | 1X lithography for large area CCD development (Intel donation)
  - | 5X wafer stepper lithography (Hewlett Packard donation)
  - | Polysilicon and silicon nitride dry etching (partially funded by Keck Telescope Science Steering Committee)
  - | Oxidation and annealing furnaces
  - | Polysilicon, silicon nitride, and silicon dioxide thin film deposition furnaces
  - | Aluminum, silicon dioxide and indium tin oxide deposition (sputtering)
- | Successful fabrication of 200 x 200, 2048 x 2048, and 2048 x 4096 (15 $\mu$ m)<sup>2</sup> CCD's

Optical/scanning-electron-microscope photographs taken after poly1 etching



# CCD Technology



- Conventional CCD fabrication technology with high-resistivity silicon
- Standard processing through the first 8 (of 10) masking steps
- After mask 8 wafers sent out for backgrinding and backside polishing
  - Standard process for thin die applications
- Deposition of thin backside ohmic contact (in-situ doped polysilicon)
  - Back-illuminated photodiode technology licensed to Digirad, Inc for nuclear medical imaging application
- Completion of remaining processing (contact/metal) with 300  $\mu\text{m}$  thick wafer, requiring lithography focus adjustment (500-600  $\mu\text{m}$  standard)
- Deposition of antireflection coatings on wafer backside

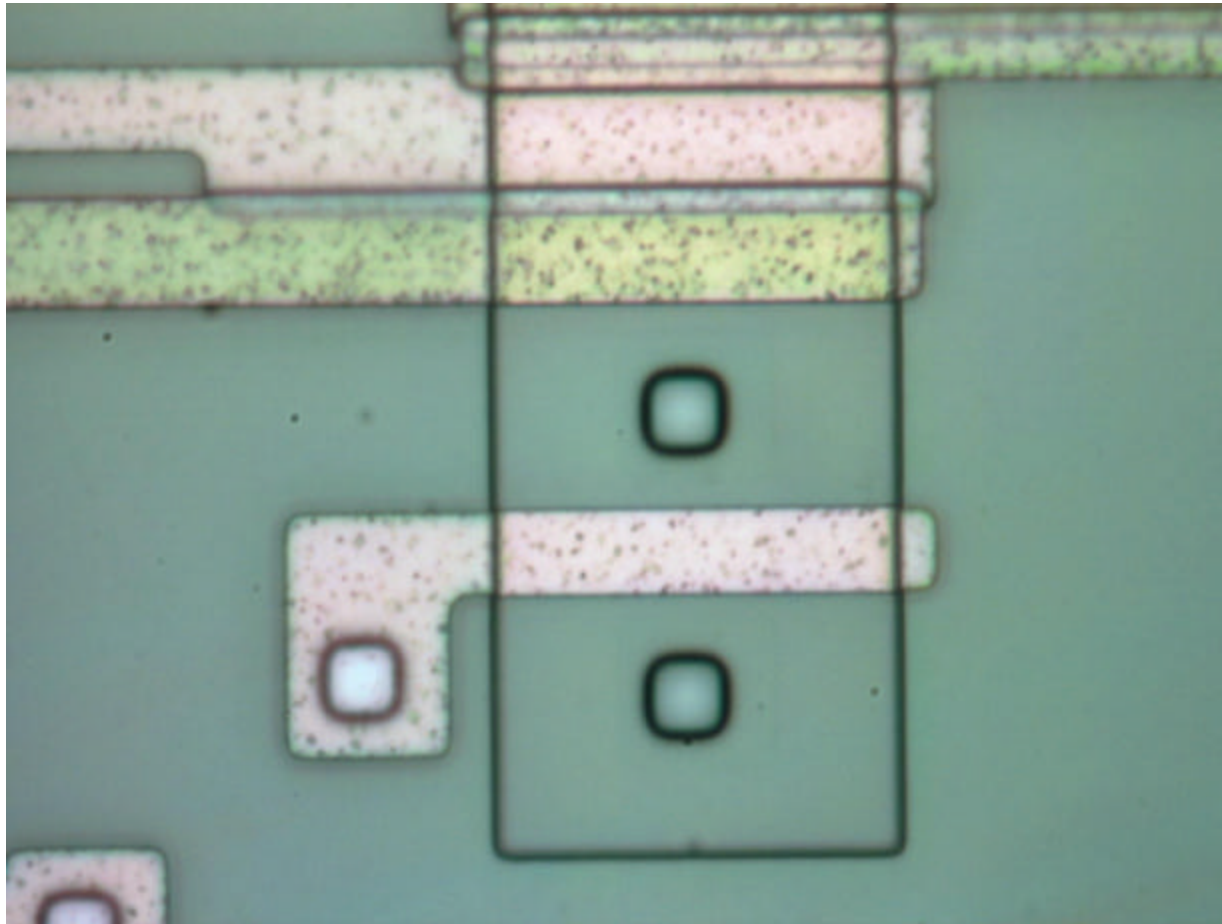
**Successful fabrication of front-illuminated control wafers at commercial vendor**

**LBNL completion of wafers processed through mask 8 by commercial vendor in progress**

# CCD Technology



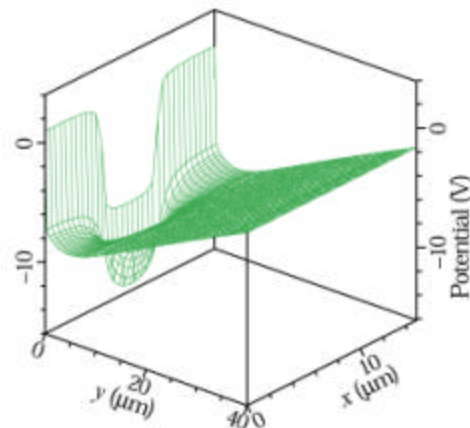
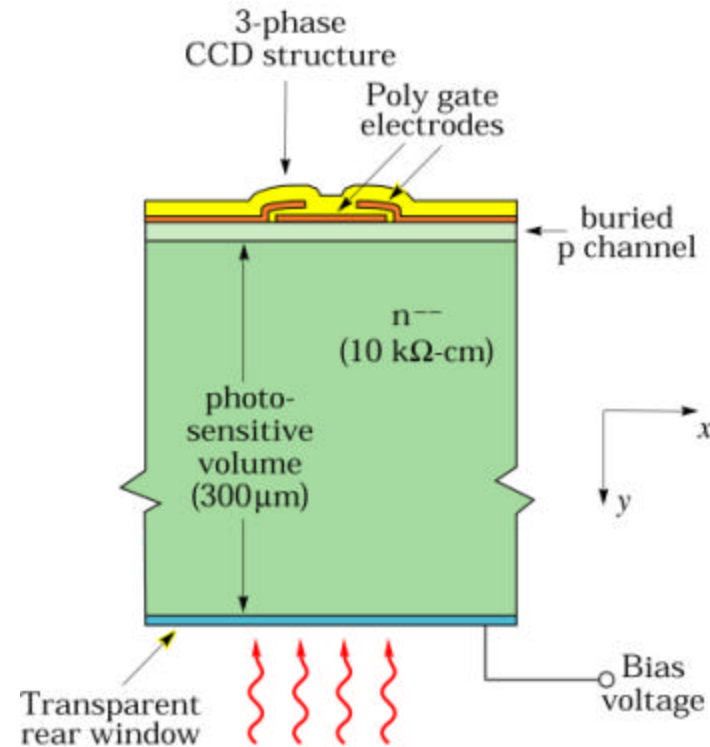
**CCD fabricated at commercial foundry through mask 8, contact etching and remaining processing performed at LBNL (in progress)**



# CCD Technology



Substrate bias voltage depletes substrate ~ independently of clock voltages

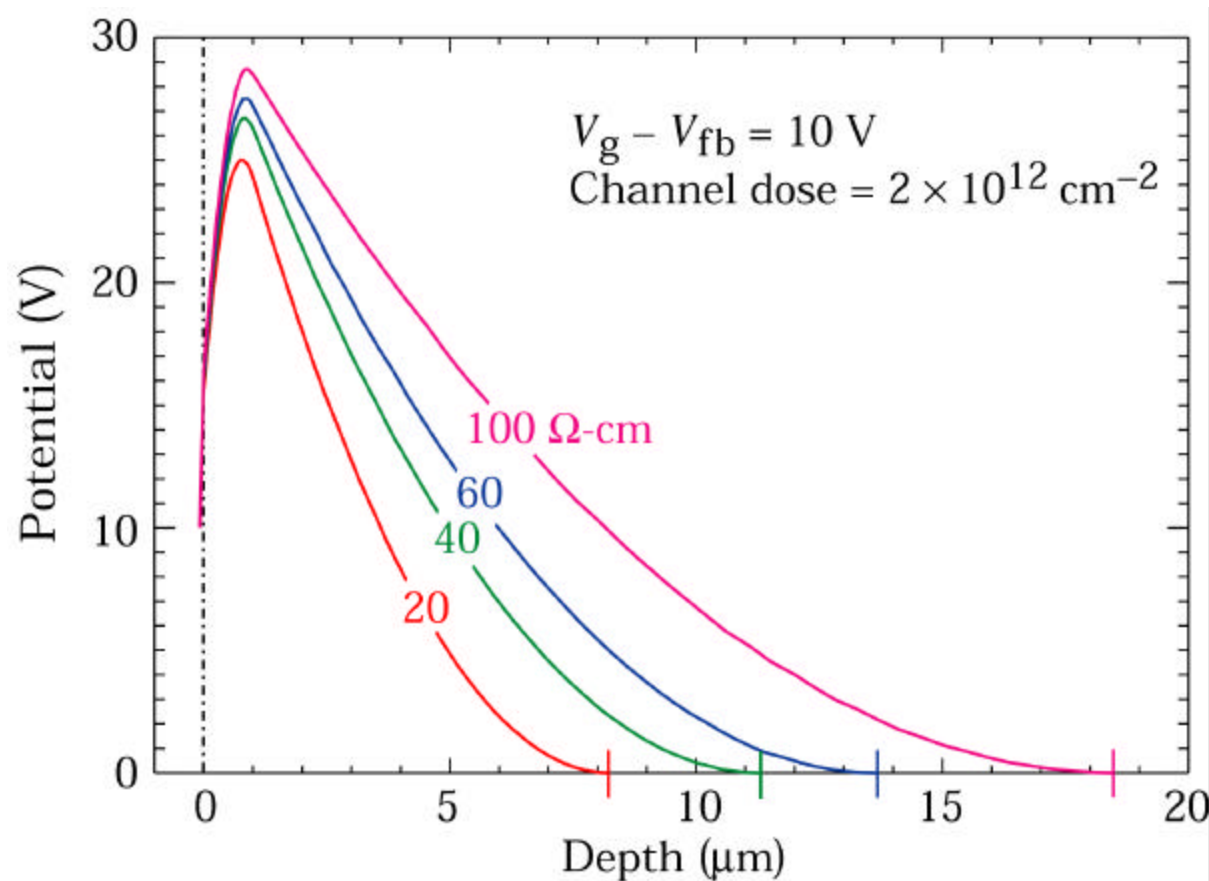


MEDICI 2-D simulation

# Point Spread Function Issues



**Low-resistivity CCD (typically 20  $\mu\text{m}$  thick): PSF dominated by carrier diffusion in field-free regions.  $s$  = Thickness of field-free region.**



Calculated CCD potential versus depth

# Point Spread Function Issues



- Fully depleted CCD: PSF determined by hole transit time in electric field
- For carriers with the same arrival time at the CCD potential wells, the distribution is Gaussian

## Constant field approximation

$$s = \sqrt{2D_p t_{tr}} \quad t_{tr} = \frac{z_{sub}}{v} = \frac{z_{sub}}{\mathbf{m}_p E} = \frac{z_{sub}^2}{\mathbf{m}_p (V_{sub} - V_J)}$$

$$D_p / \mathbf{m}_p = kT / q$$

$$s = z_{sub} \sqrt{\frac{kT}{q} \frac{2}{(V_{sub} - V_J)}}$$

$z_{sub}$  ~ Thickness of CCD

$kT / q$  Thermal voltage

$V_{sub} - V_J$  Voltage across drift region

## Hamilton Coude Echelle Spectrograph FWHM from Calibration Lamp Spectra

All CCDs have 15  $\mu\text{m}$  pixels

<i>Device</i>	<i>FWHM (pixels)</i>	<i>Notes</i>
Loral Frontside	1.25	
Loral Thinned/Backside	1.90	
LBNL Backside (300 $\mu\text{m}$ )	1.95	40V subr. bias
LBNL Backside (200 $\mu\text{m}$ )	1.60	40V subr. bias

$$\frac{\sqrt{1.60^2 - 1.25^2}}{\sqrt{1.95^2 - 1.25^2}} \approx 0.67$$

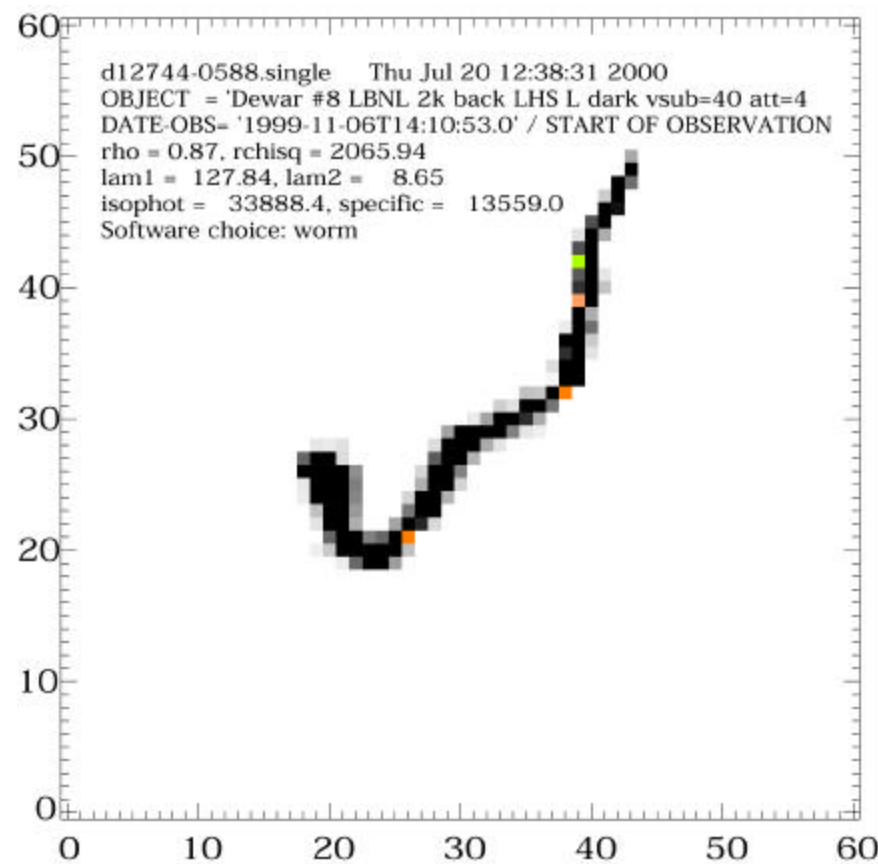
$$\mathbf{s} \approx 6.4 / 9.6 \mathbf{mm} (200 / 300 \mathbf{mm})_{V_{sub}=40V}$$

Consistent with pinhole mask/cosmic ray experiments

# Cosmic Ray/Background Radiation Issues



- Cosmic ray tracks are long
- CCD has non-negligible g efficiency
- Multiply-scattered Compton electrons yield long tracks
- Low background materials essential



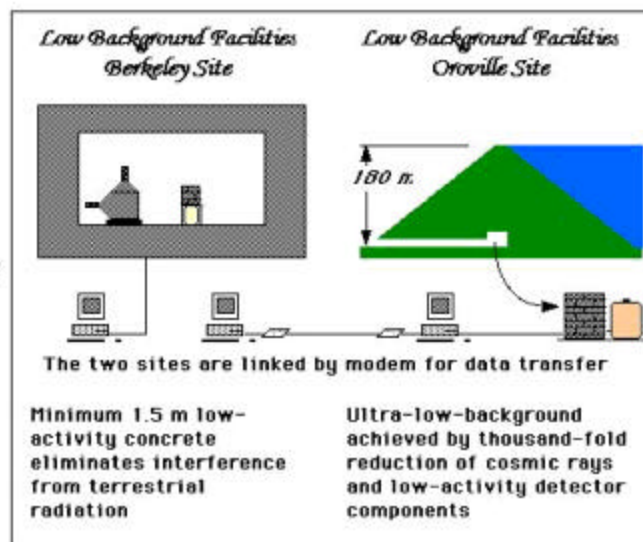
## LBNL Low Background Facilities

The Low Background Facilities are laboratories especially designed to shield out cosmic and terrestrial radiation to allow the ultra-sensitive analysis of radioactivity in samples normally considered non-radioactive. Examples of this are building materials and electronic components for neutrino and dark matter detectors, environmental samples, and cosmic ray activated samples.

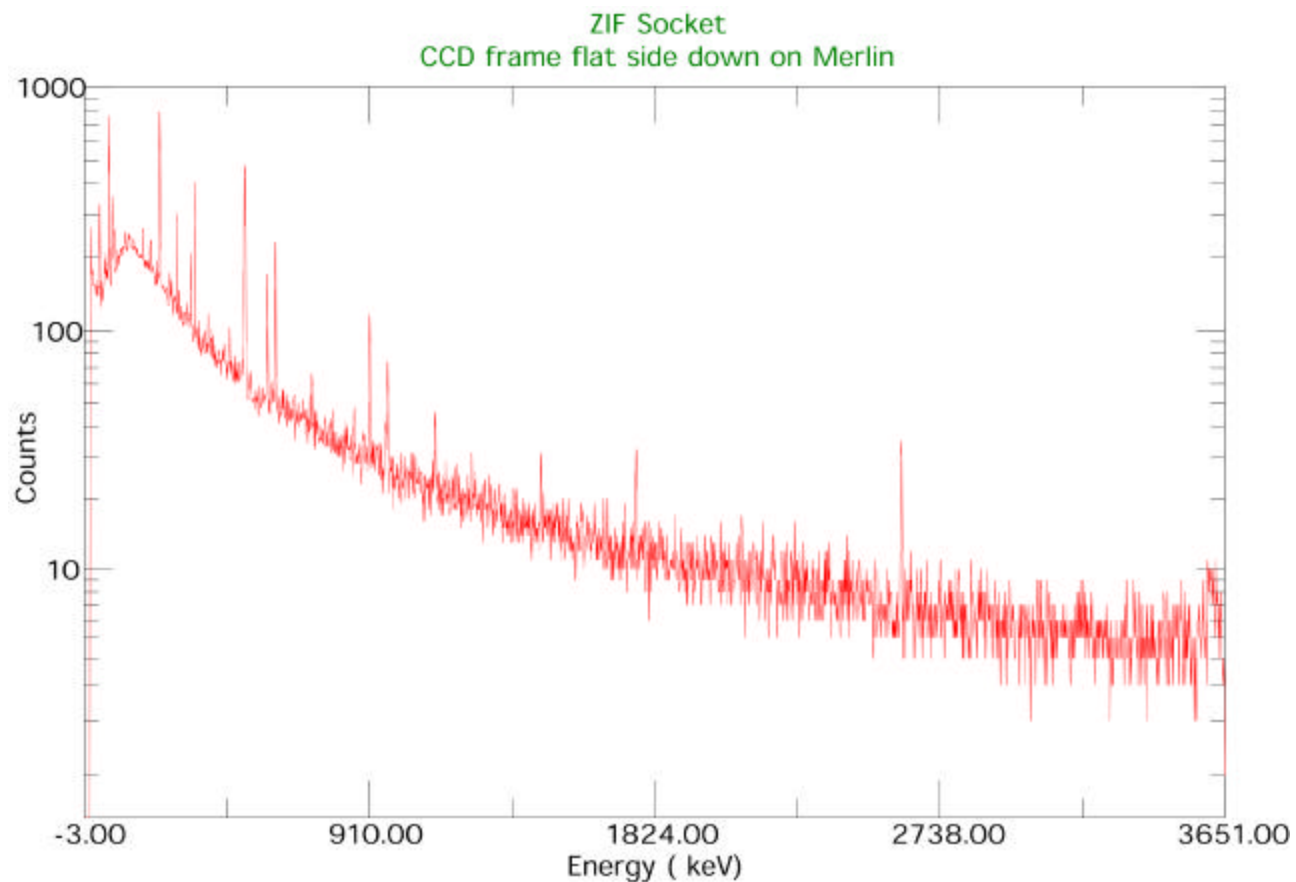
- *LBF Overview*
  - *LBF User Info*
  - *LBF Staff*
  - *LBF Publications*
  - *Neutron Activation*
  - *Field Measurements*
  - *Annual Reports*
  - *NSD Home Page*
  - *LBNL Home Page*
  - *Disclaimer*
- Site Webmaster:

Dick McDonald:  
rjmcDonald@lbl.gov

Version 2/17/99



# Materials Testing at LBNL LBF



Real Time: 237758.72 s. Live Time: 237600.39 s.  
Channels: 16384

Acquired: 4/7/00 3:39:58 PM

File: C:\D-Disk\My Documents\Steve Holland\Radiological Contamination\LBF Data\13705.chn

Detector: #4 No detector description was entered

# Key R&D Issues / Work in Progress

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- Adequate PSF for SNAP pixel size
  - High voltage operation and/or thinner wafers
- Commercialization
  - 150 mm wafer development at commercial foundry
  - Photodiode run to map dark current, first experience with 150 mm wafers
  - 2 CCD runs, with and without back illumination
  - Backup is **LBNL MicroSystems Lab**
    - 4 SNAP CCD's per 100 mm wafer vs 9 for 150 mm wafer
- Ground-based astronomy efforts
  - 2048 x 2048 for Hamilton Spectrograph at Lick Observatory (engineering runs)
  - 800 x 1980 for KPNO RC Spectrograph (2001B semester in shared-risk mode)
  - 2048 x 4096 development with **Lick CCD Testing Lab** for Keck ESI Spectrograph
- Proton irradiations at **LBNL 88" Cyclotron**
- Continued upgrading of **LBNL CCD Testing Facility**